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(54) **TUNNELING MAGNETORESISTANCE SENSOR**

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(51) **Int. Cl.**

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H01F 10/32	(2006.01)
H01L 27/22	(2006.01)

(52) **U.S. Cl.**

CPC ***H01L 43/02*** (2013.01); ***G01R 33/098*** (2013.01); ***H01F 10/3254*** (2013.01); ***H01L 27/22*** (2013.01)

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CPC B82Y 10/00; B82Y 25/00; C22C 19/07; C30B 23/02; H01L 43/10; G11B 5/3929; G01R 33/098; G01N 27/72

USPC 365/36; 257/421, E21.001, E29.323; 324/693, 252; 438/3

See application file for complete search history.

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(57) **ABSTRACT**

A tunneling magnetoresistance sensor includes a substrate, an insulating layer, a tunneling magnetoresistance component and a first electrode array. The insulating layer is disposed on the substrate. The tunneling magnetoresistance component is in contact with the insulating layer and includes at least one magnetic tunneling junction unit. The first electrode array disposed in direct contact with the insulating layer. The first electrode array includes a number of first electrodes. Each of the at least one magnetic tunneling junction unit is electrically connected to two neighboring first electrodes of the first electrode array to form a current-in-plane tunneling conduction mode.

11 Claims, 10 Drawing Sheets

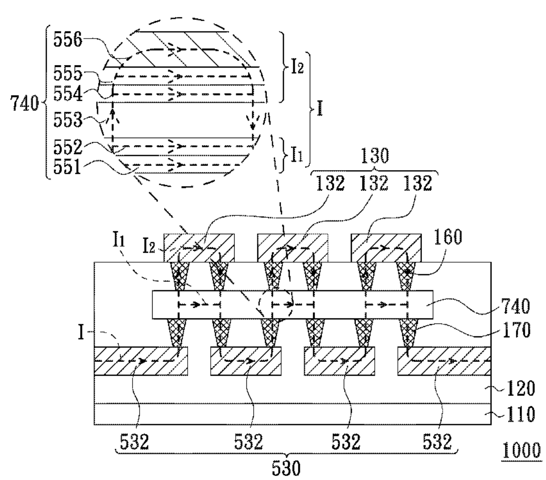

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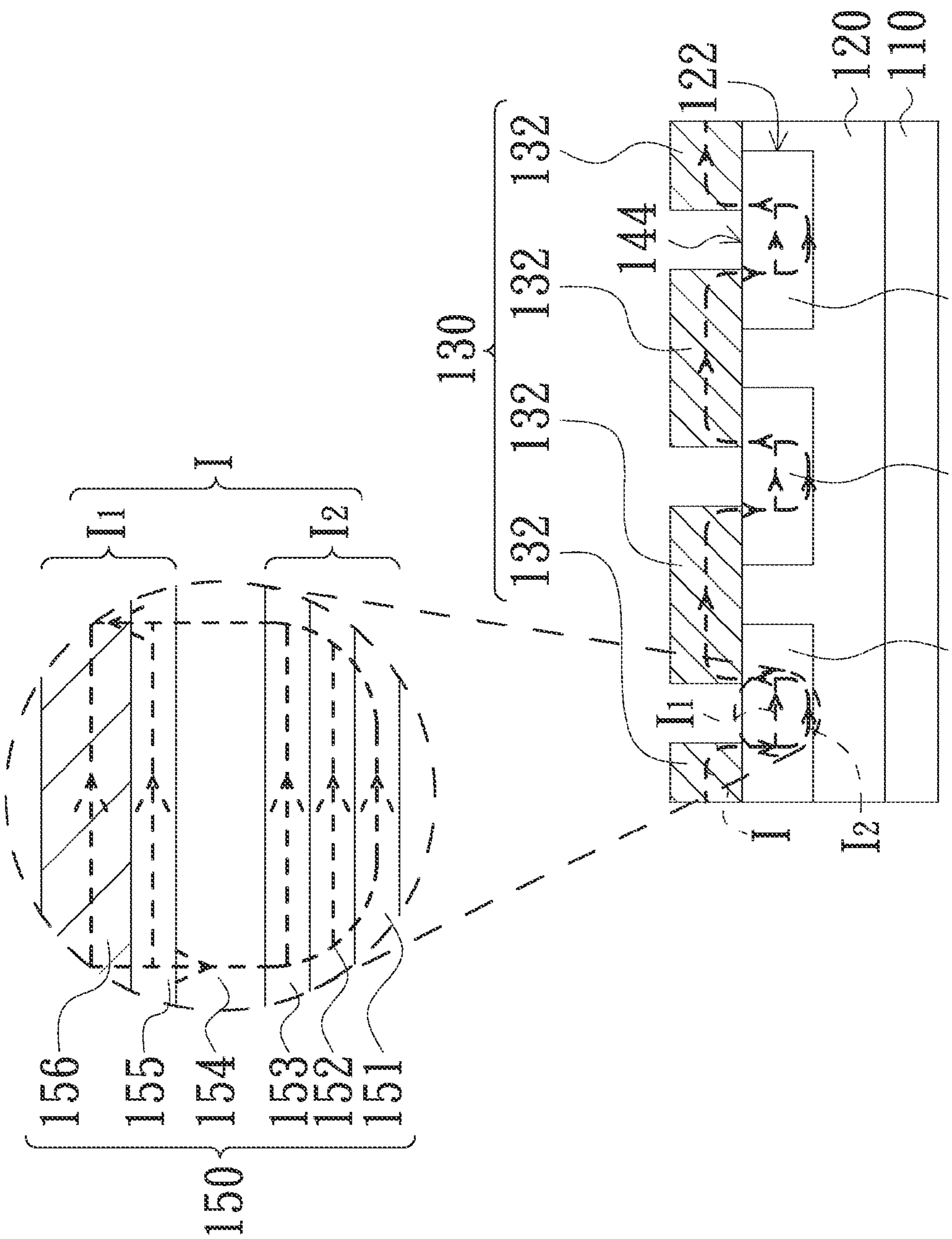
FIG. 1


100
110
120
122
130
132
140
144
150
151
152
153
154
155
156
I
I_1
I_2

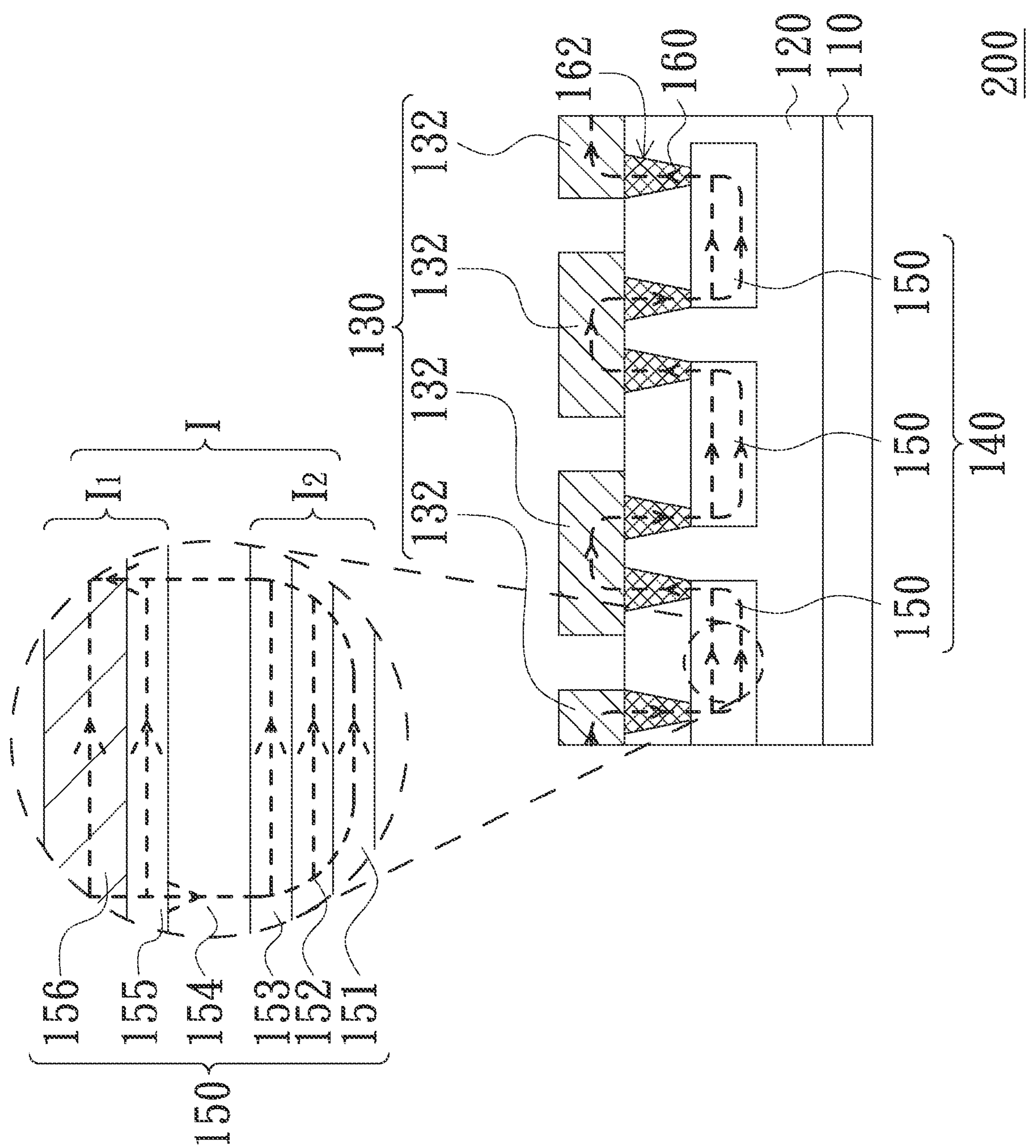
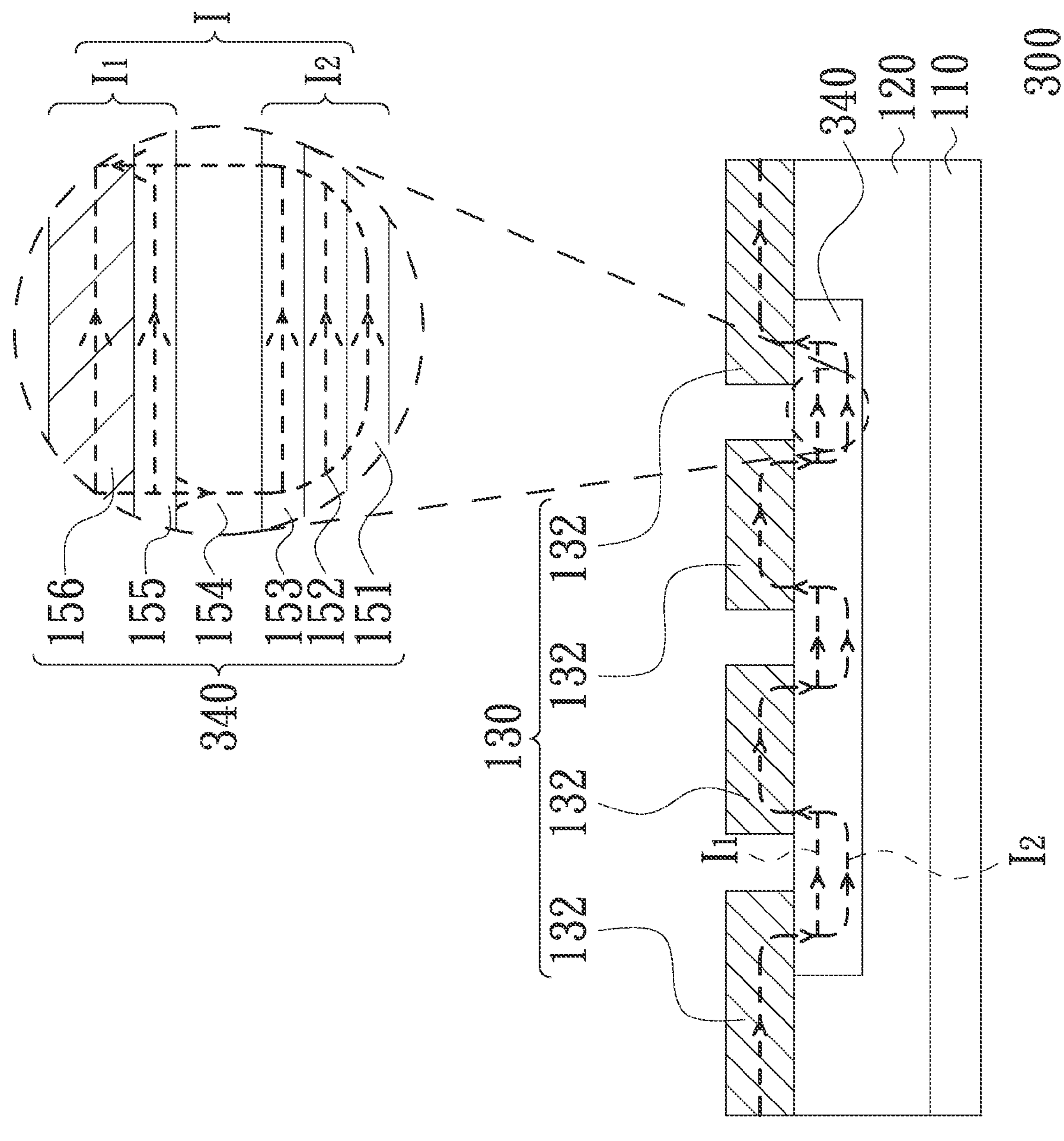

200
110
120
160
162
130
132
132
132
132
140
150
150
150
I
I_1
I_2
156
155
154
153
152
151
150

FIG. 2

FIG. 3


I
I_1
I_2
156
155
154
153
152
151
340
132
132
132
132
130
I_1
I_2
340
120
110
300

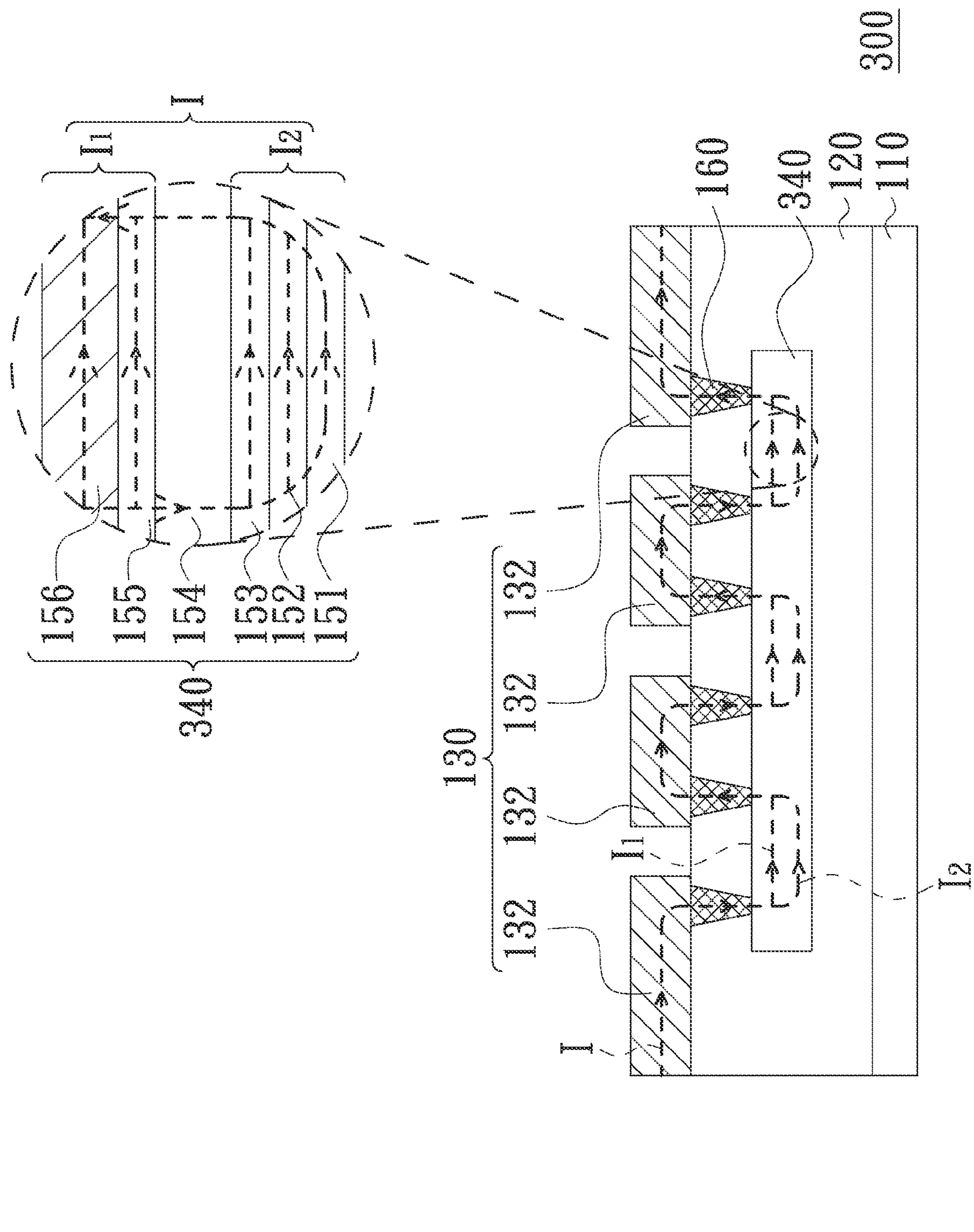

300
I
I1
I2
156
155
154
153
152
151
340
160
340
120
110
130
132
132
132
132
132
I
I1
I2

FIG. 4

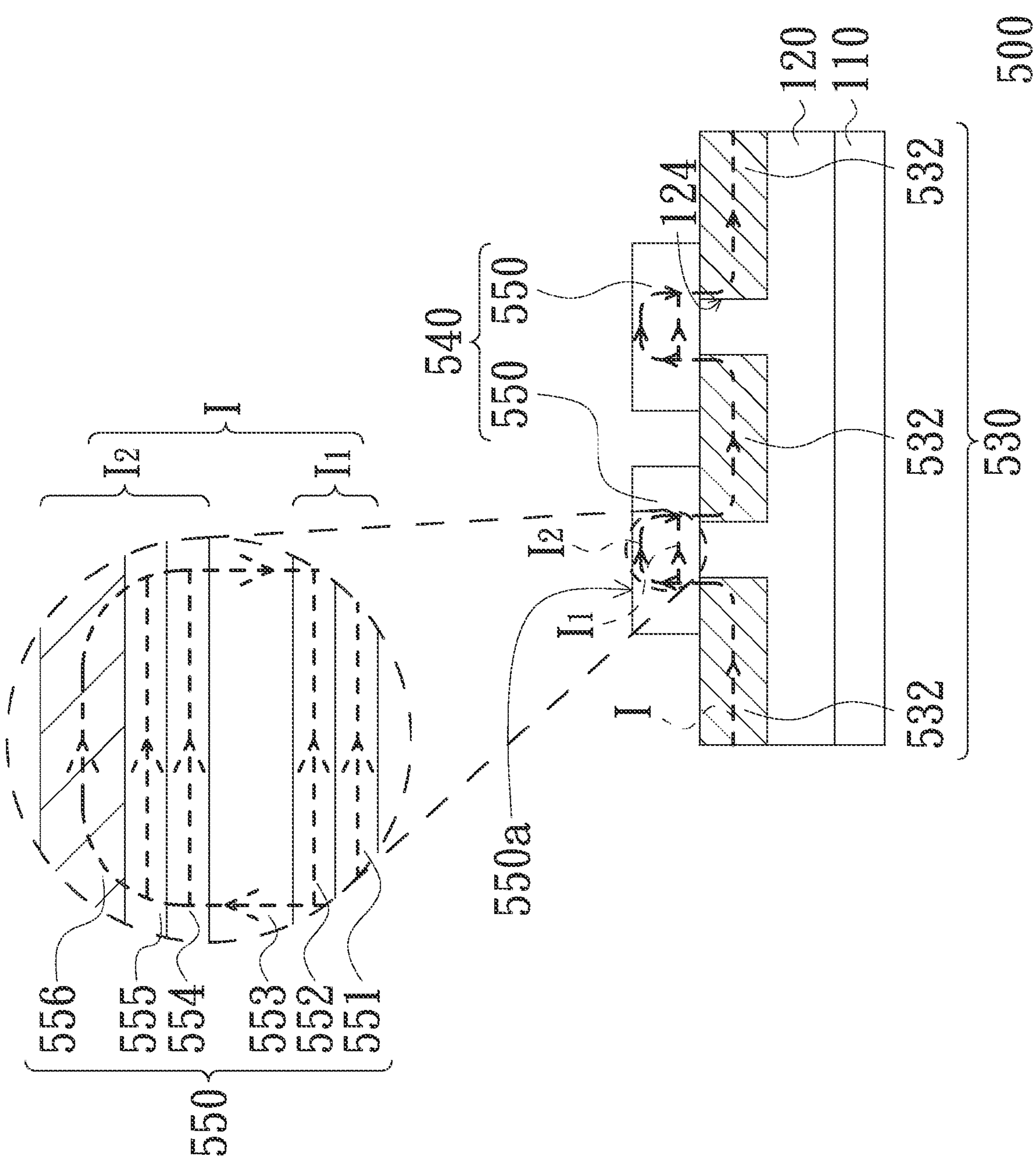
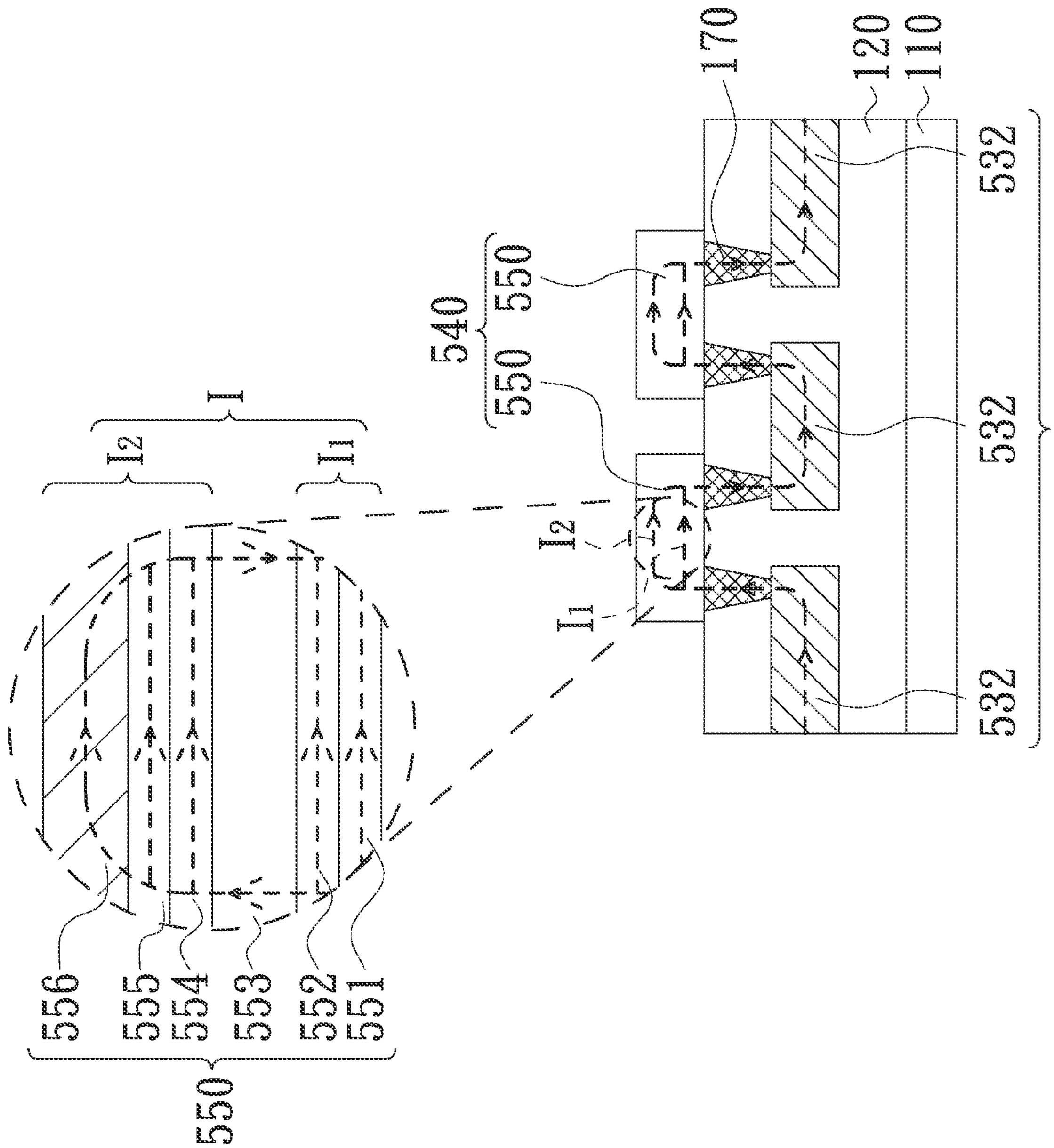

500
120
110
124
532
532
532
530
540
550
550
550a
I
I_1
I_2
551
552
553
554
555
556
550

FIG. 5

FIG. 6


170
120
110
532
532
532
530
540
550
550
I
I_2
I_1
I_2
I_1
556
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554
553
552
551
550

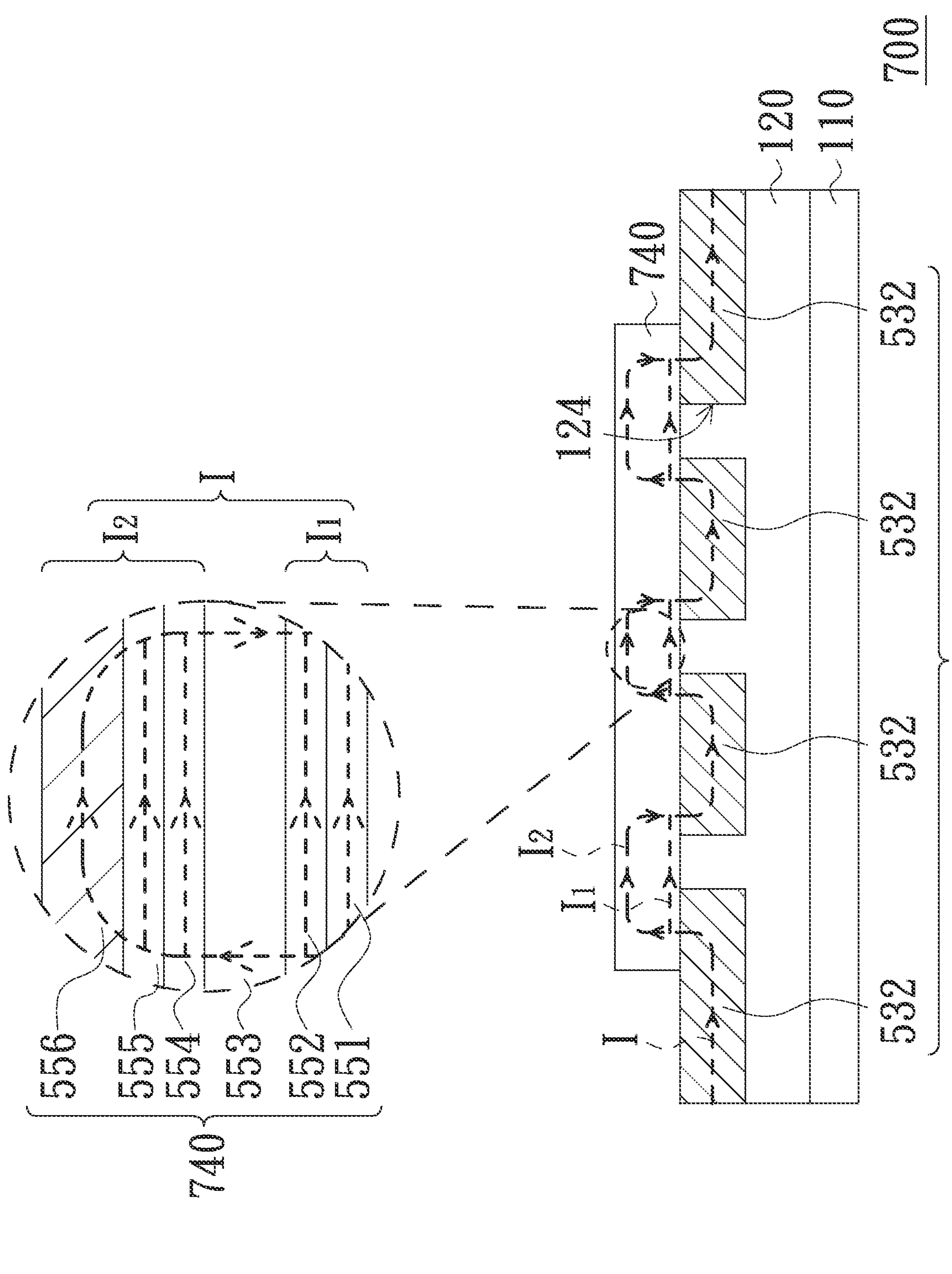

700
120
110
740
124
532
532
532
532
530
I
I1
I2
I
I1
I2
556
555
554
553
552
551
740

FIG. 7

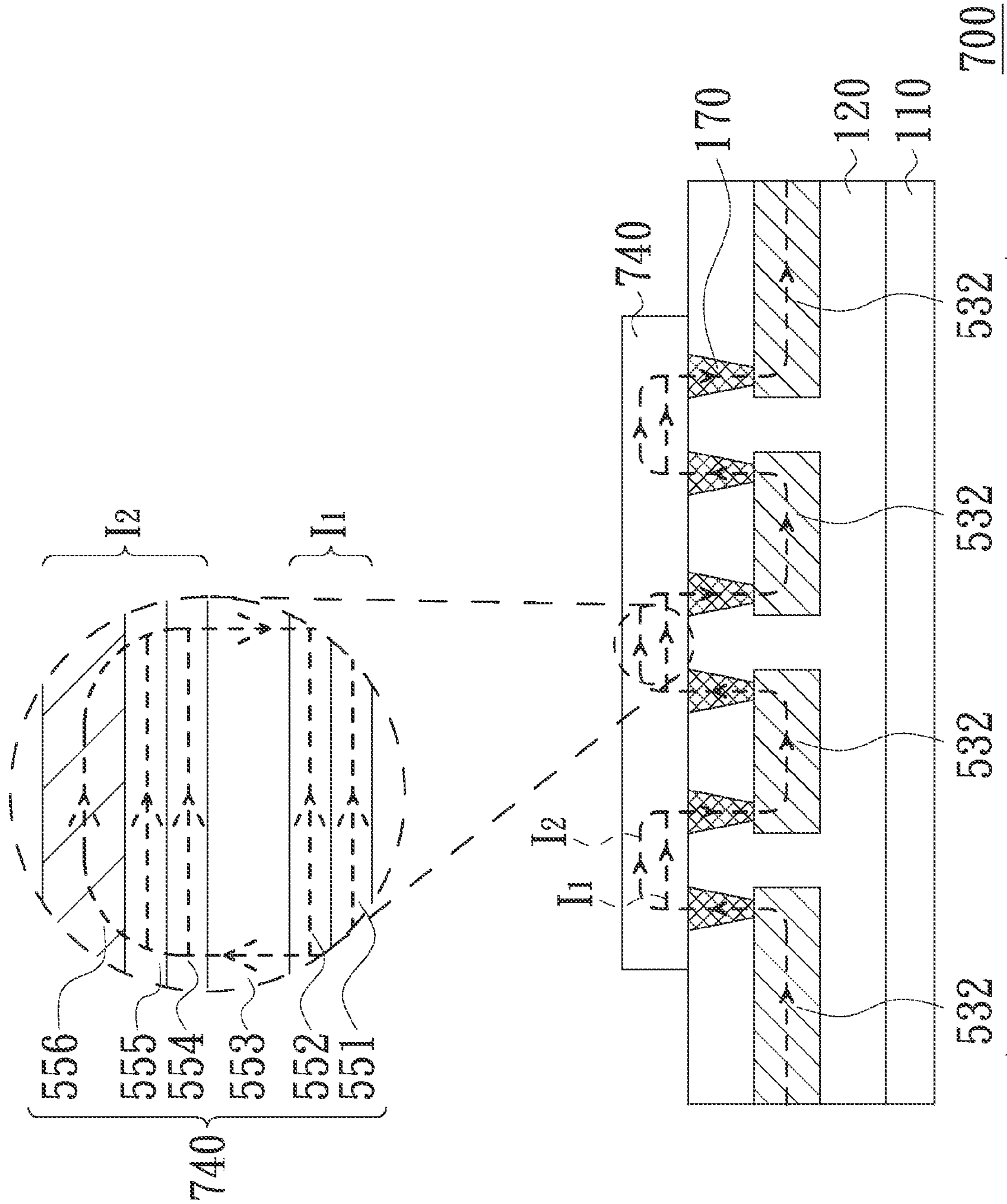
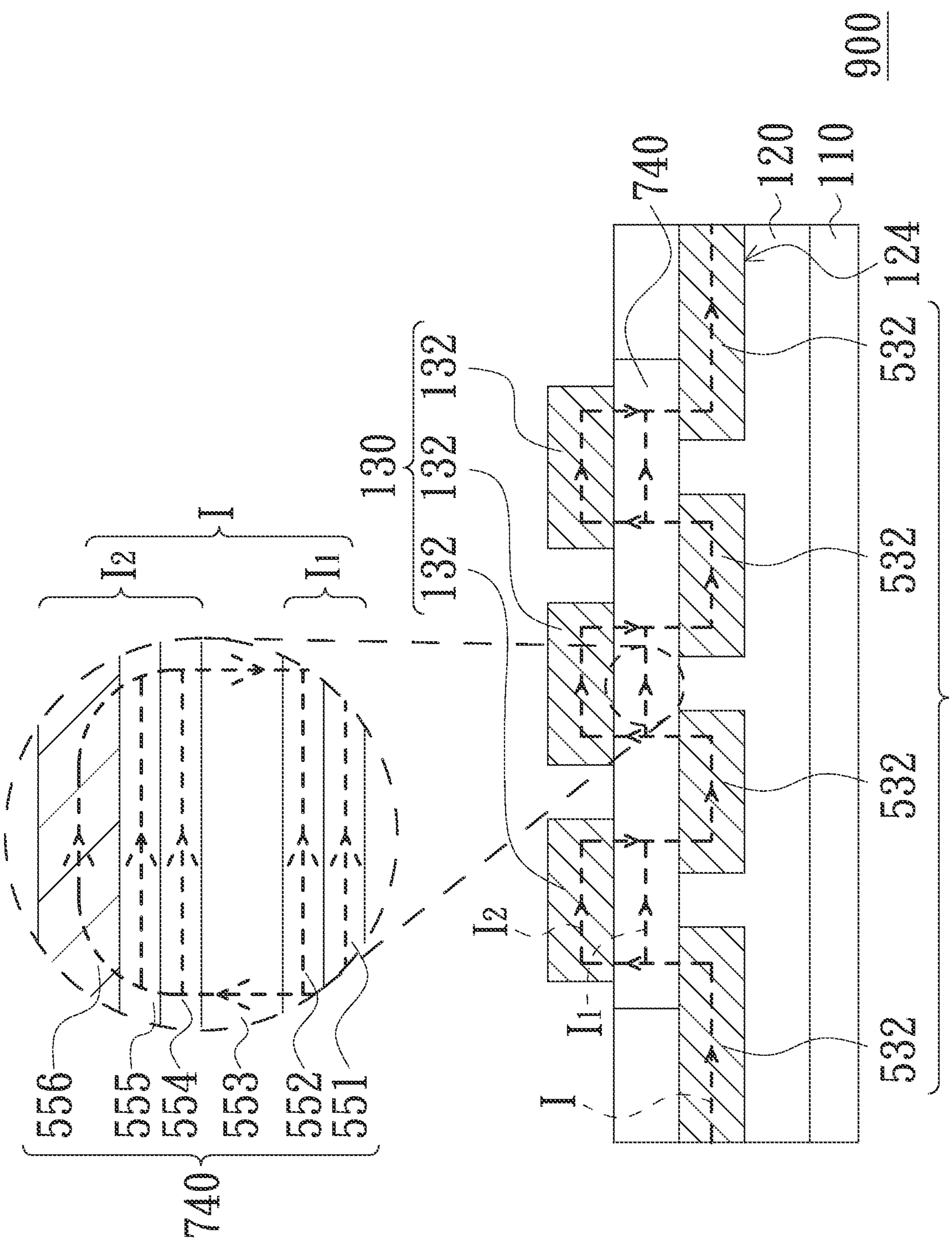

700
170
120
110
740
532
532
532
532
530
I_2
I_1
I_2
I_1
556
555
554
553
552
551
740

FIG. 8

FIG. 9


900
740
120
110
124
130
132
132
132
532
532
532
532
530
I
I2
I1
556
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554
553
552
551
740

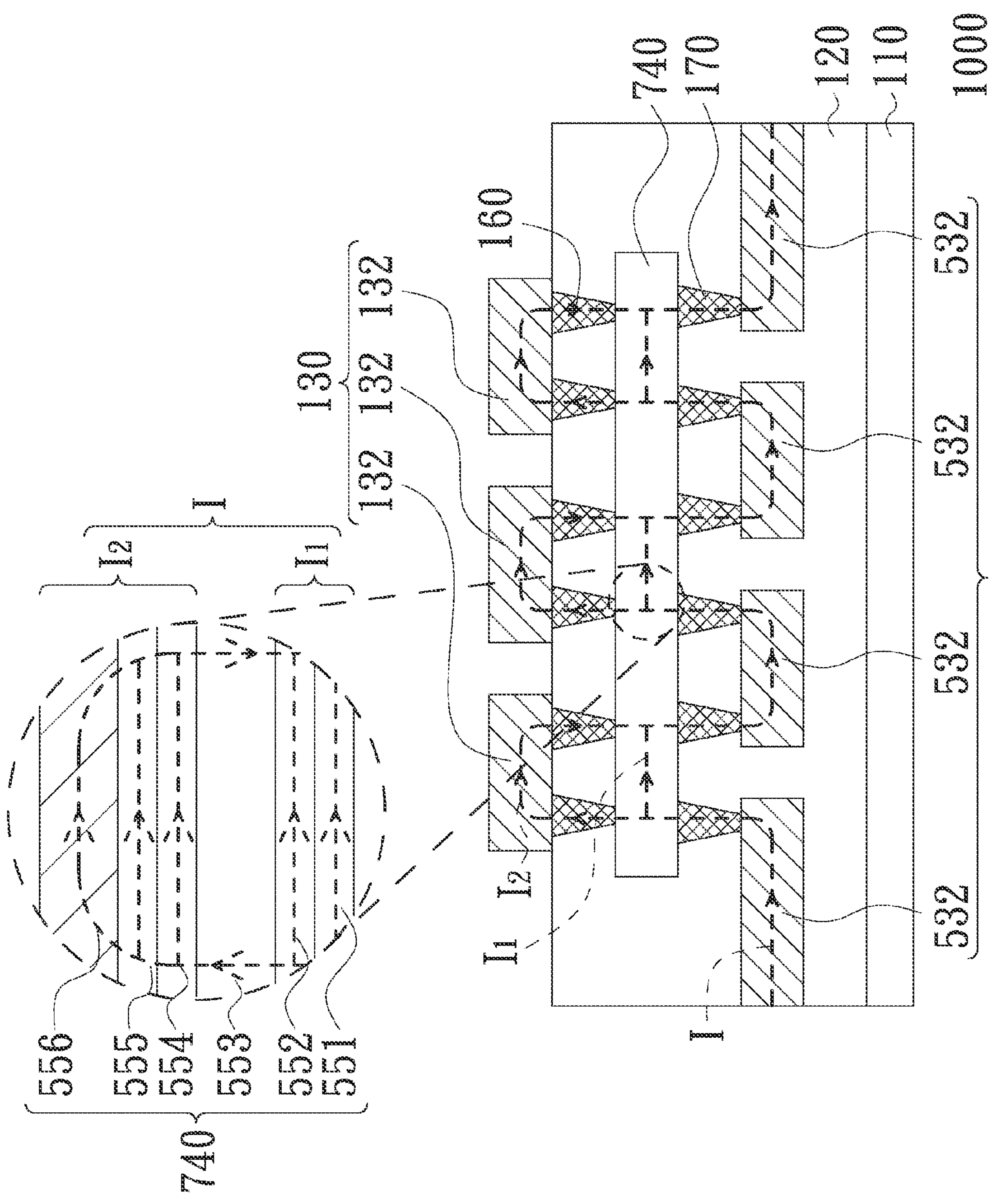
1000
110
120
170
740
160
130
132
132
132
132
532
532
532
532
530
I
I_1
I_2
I
I_2
I_1
556
555
554
553
552
551
740

FIG. 10

TUNNELING MAGNETORESISTANCE SENSOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation application of an application Ser. No. 13/333,951, filed on Dec. 21, 2011, which also claims the benefit of Taiwan Application No. 100123719 of Jul. 5, 2011. The entirety of the above-mentioned patent applications is hereby incorporated by reference herein and made a part of this specification.

FIELD OF THE INVENTION

The present invention relates to a tunneling magnetoresistance sensor, and particularly to a current-in-plane tunneling magnetoresistance (CIP-TMR) sensor.

BACKGROUND OF THE INVENTION

Recently, the tunneling magnetoresistance (TMR) mechanism has been widely employed for magnetic random access memory (MRAM) and magnetoresistance sensor applications. For example, a tunneling magnetoresistance sensor is frequently used as a rotary position sensor to sense an angular variation with high accuracy. Due to its higher magnetoresistance ratio and higher electrical resistance than a typical giant magnetoresistance (GMR) sensor, the TMR sensor has shown benefits in higher output signal, wider detection airgap and lower power consumption.

A conventional TMR device is based on the magnetic tunnel junction (MTJ) design, which comprises two ferromagnetic layers (a top ferromagnetic layer and a bottom ferromagnetic layer) separated by a thin tunnel dielectric layer. The magnetoresistance is read by applying an electric current vertically through the top ferromagnetic layer, the tunnel dielectric layer and the bottom ferromagnetic layer. In other words, the electric current has a flow direction perpendicular to the normal plane of the TMR device and conducts an upper electrode and a lower electrode adjacent to the top and the bottom ferromagnetic layers, respectively. Thus, the magnetoresistance sensor using such current conduction mode is called a current-perpendicular-to-plane tunneling magnetoresistance (CPP-TMR) sensor.

However, because the upper electrode and the lower electrode are spatially arranged on both sides of the CPP-TMR sensor, it means two metal layers are required in the structural design and the manufacturing process, which are more complicated compared with those of conventional AMR and GMR sensors.

SUMMARY OF THE INVENTION

The present invention provides a TMR sensor that can be formed by a simplified manufacturing process, thereby reducing the production cost.

The present invention provides a TMR sensor with high sensing signal and sensitivity.

The present invention provides a TMR sensor including a substrate, an insulating layer, a TMR component and a first electrode array. The insulating layer is disposed on the substrate. The TMR component is in contact with the insulating layer. The TMR component includes at least one MTJ unit. The first electrode array is disposed in contact with the insulating layer. The first electrode array includes a number of first electrodes. The first electrodes are electrically connected to the TMR component to form a current-in-plane tunneling conduction mode, wherein each of the at least one MTJ unit is electrically connected to two neighboring first electrodes of the first electrode array.

In the present invention, the TMR sensor can function with only one electrode array. That is, only one metal layer is required for reading the TMR signal. Such configuration with the electrodes on one side of the TMR component is referred to as current-in-plane tunneling magnetoresistance (CIP-TMR). In comparison with conventional CPP-TMR sensor, the CIP-TMR sensor of the present invention can be manufactured with less metal layers, thereby reducing the production cost.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objects and advantages of the present invention will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, in which:

FIG. **1** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with an embodiment of the present invention.

FIG. **2** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with another embodiment of the present invention.

FIG. **3** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with still another embodiment of the present invention.

FIG. **4** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with still another embodiment of the present invention.

FIG. **5** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with still another embodiment of the present invention.

FIG. **6** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with still another embodiment of the present invention.

FIG. **7** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with still another embodiment of the present invention.

FIG. **8** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with still another embodiment of the present invention.

FIG. **9** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with still another embodiment of the present invention.

FIG. **10** illustrates a partial, cross-sectional, schematic view of TMR sensor in accordance with still another embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention will now be described more specifically with reference to the following embodiments. It is to be noted that the following descriptions of preferred embodiments of this invention are presented herein for purpose of illustration and description only. It is not intended to be exhaustive or to be limited to the precise form disclosed.

FIG. **1** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with an embodiment of the present invention. Referring to FIG. **1**, a TMR sensor **100** includes a substrate **110**, an insulating layer **120**, an electrode array **130** and a TMR component **140**. The substrate **110** can be, for example, a silicon substrate covered by an insulating material or a silicon wafer having front-end logic circuits. The insulating layer **120** is formed on the substrate **110**. The TMR component **140** is embedded in the insulating layer **120**. In the present embodiment, the TMR component **140** includes a number of magnetic tunneling junction (MTJ) units **150**. The MTJ units **150** are separated from each other. In detail, in the present embodiment, in a process of manufacturing the TMR sensor **100**, firstly a lower insulating layer (not labeled) is formed on the substrate **110**. Then, the MTJ units **150** are formed on the lower insulating layer. Next, an upper insulating layer (not labeled) may be formed to cover the MTJ units **150** and the lower insulating layer. The upper insulating layer and the lower insulating layer constitute the insulating layer **120**. A chemical mechanical polishing process is then performed so that the upper surface of the upper insulating layer is planarized and a number of openings **122** are formed in the insulating layer **120**. The MTJ units **150** are embedded in the openings **122** and the top surfaces of the MTJ units **150** are exposed from the insulating layer **120**. There is another manufacturing process which may not involve the deposition of the upper insulating layer. Next, the electrode array **130** is formed on the MTJ units **150** and the insulating layer **120**. An additional passivation layer (not shown) can also be applied on the TMR sensor **100** for protection and reliability concern.

The electrode array **130** includes a number of electrodes **132**. The electrodes **132** are separately disposed on the insulating layer **120** and the MTJ units **150**, and electrically connected to the MTJ units **150**. That is, the electrode array **130** is adjacent to and electrically in contact with the TMR component **140**. The electrodes **132** of the electrode array **130** are formed in a single metal layer. In the present embodiment, a material of the electrodes **132** is, for example, aluminum. In detail, two neighboring electrodes **132** are electrically connected to a common MTJ unit **150** on both ends. The MTJ units **150** and the electrodes **132** are arranged alternately in the form of contact chain. That is, each electrode **132** is disposed between and electrically connected to two neighboring MTJ units **150**, and each MTJ unit **150** is disposed between and electrically connected to two neighboring electrodes **132**.

It is noted that, the contact chain formed by alternate the MTJ units **150** and the electrodes **132** may not be aligned in a straight line. The MTJ units **150** should have identical shape and dimension, and should be aligned in parallel in the same direction. While the electrodes **132** do not have the same limitations. It means the contact chain may appear in a serpentine-like structure for ease of routing purpose.

Additionally, it is familiar that the electrodes **132** are electrically connected to a circuit by metal interconnections or other means. In order to expressively illustrate the TMR sensor **100**, the detailed electrical connection of the electrodes **132** to the circuit is not shown in FIG. **1**.

Again, referring to FIG. **1**, in the present embodiment, each of the MTJ units **150** includes a pinned layer **153**, a free layer **155** and a tunnel barrier **154** in between.

Specifically, the MTJ units **150** may further include a seed layer **151**, an exchange bias layer **152** and a hard mark **156**. The seed layer **151**, the exchange bias layer **152**, the pinned layer **153**, the tunnel barrier **154**, the free layer **155** and the hard mark **156** are stacked on the insulating layer **120** sequentially in that order. In another embodiment, the seed layer **151**, the free layer **155**, the tunnel barrier **154**, the pinned layer **153**, the exchange bias layer **152** and the hard mark **156** can also be stacked on the insulating layer **120** sequentially in that order.

The seed layer **151** is firstly formed so that the subsequent layers can grow with a good texture and a preferred orientation. The exchange bias layer **152** is configured to fix a magnetization direction of the pinned layer **153**. The exchange bias layer **152** is made of an anti-ferromagnetic material. The pinned layer **153** and the free layer **155** are made of a ferromagnetic material comprising iron, cobalt, nickel or combination thereof. For example, the pinned layer **153** and the free layer **155** can be a pure-element layer, an alloy layer or a composite layer which belongs to the ferromagnetic material. The magnetization direction of the pinned layer **153** is fixed due to the interlayer exchange coupling effect with the exchange bias layer **152**. The magnetization direction of the free layer **155** is variable when under an applied magnetic field. Such angel variation between the magnetization direction of the free layers **155** and the magnetization direction of the pinned layers **153** leads to change in resistance value. The tunnel barrier **154** has a high selectivity with respect to spin electrons in different states and accounts for high TMR ratio. A material of the tunnel barrier **154** can be, for example, aluminum oxide or magnesium oxide. The hard mark layer **156** is made of a high etching selectivity material, for example, tantalum or chrome silicide, during etching the ferromagnetic material.

According to the principle of the current-in-plane tunneling, (CIPT), the MTJ units **150** should have an optimum current traveling distance. Thus, when an electric current I flows from one electrode **132** of the electrode array **130** into the MTJ unit **150** electrically connected to the one electrode **132**, one portion (i.e., partial current I**1**) of the electric current I flows directly through the hard mark layer **156** and the free layer **155** parallel to the reference plane **144** and arrives at the other electrode **132** connected to the same MTJ unit **150**. Meanwhile, the other portion (i.e., partial current I**2**) of the electric current I tends to form a secondary path so as to reduce the whole resistance. In detail, the partial current I**2** originates from the one electrode **132** and goes vertically through the hard mask **156** and the free layer **155**, across the tunnel barrier **154**, and into the seed layer **151**, the exchange bias layer **152** and the pinned layer **153**. After traveling a certain distance, the partial current I**2** again goes across the tunnel barrier **154**, through the free layer **155** and hard mask layer **156**, and finally reaches the other electrode **132** connected to the same MTJ unit **150**. In other words, in the TMR sensor **100** of the present embodiment, a flow direction of the electric current I is parallel to the reference plane **144** of the MTJ unit **150**. Moreover, the electrodes **132** via which the electric current I flowing out and in are arranged at the same side (top side) of the MTJ unit **150**. Thus, the TMR sensor **100** is a current-in-plane tunneling magnetoresistance sensor.

It is noted that, although the electrodes **132** as mentioned are physically and electrically connected to the MTJ units **150**, the electrical connection method of the electrodes **132** and the MTJ units **150** is not limited by the embodiment disclosed above. FIG. **2** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with another embodiment of the present invention. Referring to FIG. **2**, the TMR sensor **200** in the present embodiment is similar to the TMR sensor **100** except that the TMR sensor **200** further includes a number of contact plugs **160**. The contact plugs **160** are formed in the insulating layer **120** and electrically connect the electrodes **132** with corresponding MTJ units **150**. The contact plugs **160** are placed at the corresponding positions where the electrodes **132** are intentionally disposed to connect with the MTJ units **150**. Thus, two neighboring electrodes **132** are electrically connected to a common MTJ unit **150** by the contact plugs **160** therebetween. For ease of schematic view, only one contact plug **160** is indicated at each corresponding position.

It is noted that, in the present embodiment, the contact plugs **160** can be conventional tungsten plugs. In another embodiment, after a number of contact holes **162** are formed, the contact plugs **160** and the electrode array **130** can be simultaneously formed by using a metal layer (e.g., an aluminum layer). The manufacturing process of the contact plugs **160** and the electrode array **130** is similar to a typical interconnection process, and is not described here.

Particularly, a magnetoresistance ratio (MR ratio) of each of the MTJ units **150** is related to a distance of the two neighboring electrodes **132** connected thereto. The distance of two neighboring electrodes **132** should be in an optimum range. If the distance of two neighboring electrodes **132** is too far or too close, the MR ratio of the MTJ unit **150** will be decreased. In addition, the width and aspect ratio of each of the MTJ units **150** will affect the switching field of the free layer **155**. The free layer **155** shows higher coercivity when the MTJ units **150** are in smaller width and lower aspect ratio. That is, the free layer **155** requires higher applied field to switch the magnetic moment thereof, thereby reducing the sensing sensitivity. Therefore, in order to enhance the sensing sensitivity by reducing switching field, the width and aspect ratio of each MTJ unit **150** can be increased. In other embodiments, as shown in FIG. **3** and FIG. **4**, a TMR component **340** including a strip-shaped MTJ unit is formed in the insulating layer **120** to reduce the switching field.

According to the principle of the current-in-plane tunneling, (CIPT), if only two electrodes **132** of the electrode array **130** are electrically connected to two ends of the strip-shaped TMR component **340**, the distance between the two electrodes **132** will be too far. Thus, the MR ratio of the TMR component **340** will be greatly reduced. This is because the TMR resistance change arising from spin electrons across the tunnel barrier **154** becomes much less weighted when compared to the total resistance dominated by the in-plane conduction resistance. In order to increase the amount of TMR resistance change, a number of electrodes **132** can be formed and electrically connected to the TMR component **340**. In such circumstance, the electric current may have higher probability to traverse the tunnel barrier **154** many times, thereby achieving a multiple tunneling effect to increase the MR ratio of the TMR component **340**.

Accordingly, the MR ratio of the TMR component **340** can be increased while the switching field is decreased, thereby increasing the sensing sensitivity of the TMR sensor **300**.

It is noted that, the shape of the TMR component **340** is not limited by the present embodiment. The TMR component **340** can be a long strip or other elongated shapes.

Similarly, the TMR component **340** can be physically and electrically connected to the electrode array **130**, as shown in FIG. **3**. Also, the TMR component **340** can be electrically connected to the electrode array **130** by the contact plugs **160**, as shown in FIG. **4**.

FIG. **5** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with still another embodiment of the present invention. Referring to FIG. **5**, a TMR sensor **500** includes a substrate **110**, an insulating layer **120**, an electrode array **530** and a TMR component **540**. The substrate **110** can be, for example, a silicon substrate covered by an insulating material or a silicon wafer having front-end logic circuits. The insulating layer **120** is formed on the substrate **110**. In the present embodiment, the insulating layer **120** defines a number of openings **124**. The electrode array **530** includes a number of electrodes **532**. The electrodes **532** are separated from each other and embedded in the openings **124**. The top surfaces of the electrodes **532** are exposed from the insulating layer **120** through the corresponding openings **124**. In detail, in the present embodiment, the insulating layer **120** is patterned by a photolithography process or other suitable processes so as to form the openings **124**. Then, a metal material such as tungsten or copper is filled into the openings **124** by a damascene process so as to form the electrodes **532**.

Similar to the electrodes **132** in the aforesaid embodiments, the electrodes **532** in the present embodiment are electrically connected to a circuit by metal interconnections or other means. In order to expressively illustrate the TMR sensor **500**, the detailed electrical connection of the electrodes **532** to the circuit is not shown in FIG. **5**.

Still, referring to FIG. **5**, in the present embodiment, the TMR component **540** is disposed on the insulating layer **120** and electrically connected to the electrode array **530**. The TMR component **540** includes a number of MTJ units **550** and the MTJ units **550** are separated from each other. Each of the MTJ units **550** is electrically connected to two neighboring electrodes **532**. In other words, two neighboring electrodes **532** are electrically connected to a common MTJ unit **550** on both ends. An additional passivation layer (not shown) can also be applied on top of the TMR sensor **500** for protection and reliability concern.

In the present embodiment, each of the MTJ units **550** includes a free layer **552**, a pinned layer **554**, and a tunnel barrier **553** in between.

Specifically, the MTJ units **550** may further include a seed layer **551**, an exchange bias layer **555** and a hard mark **556**. The seed layer **551**, the free layer **552**, the tunnel barrier **553**, the pinned layer **554**, the exchange bias layer **555**, and the hard mark **556** are stacked on the insulating layer **120** sequentially in that order and electrically in contact with the corresponding electrodes **532**. In another embodiment, the seed layer **551**, the exchange bias layer **555**, the pinned layer **554**, the tunnel barrier **553**, the free layer **552**, and hard mask **556** can also be stacked on the insulating layer **120** sequentially in that order and electrically in contact with the corresponding electrodes **532**.

It is noted that, the materials of the seed layer **551**, the free layer **552**, the tunneling barrier **553**, the pinned layer **554**, the exchange bias layer **555**, and the hard mark **556** are respectively similar to or identical to the material of the seed layer **151**, the free layer **155**, the tunneling barrier **154**, the pinned layer **153**, the exchange bias layer **152**, and the hard mark **156** in aforesaid embodiments, and are not described here.

According to the principle of the current-in-plane tunneling, the MTJ units **550** should have an optimum current traveling distance. Thus, when an electric current I flows from one electrode **532** of the electrode array **530** into the MTJ unit **550** electrically connected to the one electrode **532**, one portion (i.e., partial current I1) of the electric current I flows directly through the seed layer **551** and the free layer **552** parallel to the reference plane **550***a* and arrives at the other electrode **532** connected to the same MTJ unit **550**. Meanwhile, the other portion (i.e., partial current I2) of the electric current I tends to form a secondary path so as to reduce the whole resistance. In detail, the partial current I2 originates from the one electrode **532** and goes vertically through the seed layer **551** and the free layer **552**, across the tunnel barrier **553**, and into the pinned layer **554**, the exchange bias layer **555** and the hard mask **556**. After traveling a certain distance, the partial current I2 again goes across the tunnel barrier **553**, through the free layer **552** and the seed layer **551**, and finally reaches the other electrode **532** connected to the same MTJ unit **550**. In other words, in the TMR sensor **500** of the present embodiment, a flow direction of the electric current I is parallel to the reference plane **550***a* of the MTJ unit **550**. Moreover, the electrode **532** via which the electric current I flowing out and in are arranged at the same side (bottom side) of the

MTJ unit **550**. Thus, the TMR sensor **500** is a current-in-plane tunneling magnetoresistance sensor.

As shown in FIG. **5**, in the present embodiment, the TMR component **540** of the TMR sensor **500** is disposed on the electrode array **530** and electrically connected to the electrode array **530**. That is, the electrode array **530** is adjacent to the TMR component **540**. After the formation of TMR component **540**, no further metal layer is disposed above the TMR component **540**. It is noted that, by such arrangement, the TMR component **540** can avoid the deterioration of the metal-layer manufacturing process, such as thermal energy accumulation, stress accumulation and interface diffusion. Thus, the performance of the TMR component **540** will be maintained.

It is noted that, although the electrodes **532** are physically and electrically connected to the MTJ units **550**, the way of electrical connection between the electrodes **532** and the MTJ units **550** is not limited by the embodiment disclosed above. In another embodiment, referring to FIG. **6**, the TMR sensor further includes a number of contact plugs **170**. The contact plugs **170** are formed in the insulating layer **120**. The contact plugs **170** electrically connect the electrode array **530** with corresponding MTJ units **550**.

Additionally, the MR ratio of the TMR component can be increased while the switching field is decreased, thereby increasing the sensing sensitivity of the TMR sensor. As shown in FIG. **7** and FIG. **8**, a TMR component **740** including a strip-shaped MTJ unit is substituted for the TMR component **540** including the MTJ units **550** as shown in FIG. **5** and FIG. **6**. In the TMR sensor **700**, as shown in FIG. **7** and FIG. **8**, the TMR component **740** is disposed on the insulating layer **120**, and the electrode array **530** is embedded in the insulating layer **120**. The electrode array **530** can form electrical connection with the TMR component **740** by either direct contact or assistance of contact plugs **170**. The other structures of the TMR sensor **700** are similar to or identical to the TMR sensor **300**, and are not described here.

FIG. **9** illustrates a partial, cross-sectional, schematic view of a TMR sensor in accordance with still another embodiment of the present invention. Referring to FIG. **9**, a TMR sensor **900** includes a TMR component **740** including a strip-shaped MTJ unit. It is noted that, the TMR sensor **900** further includes a secondary electrode array **130** disposed on, adjacent to and electrically connected with the TMR component **740** besides a primary electrode array **530** disposed below, adjacent to and electrically connected with the TMR component **740**. That is, the TMR component **740** is located between the primary electrode array **530** and the secondary electrode array **130**. In detail, the primary electrode array **530** includes a number of electrodes **532** disposed in the openings **124** of the insulating layer **120**. The secondary electrode array **130** includes a number of electrodes **132** disposed on the TMR component **740**. The electrodes **532** of the primary electrode array **530** are formed in a single metal layer, and the electrode electrodes **132** of the secondary electrode array **130** are formed in another single metal layer. The electrodes **132** and the electrodes **532** are arranged alternately along the extending direction of the strip-shaped MTJ unit. Only the electrodes **532** at two ends of the TMR component **740** lead to the metal interconnections. The other electrodes **532** as well as all the electrodes **132** are electrically in contact with the TMR component **740** only. That is, the electrode array **130** is not electrically connected to the metal interconnections. It is noted that, in other embodiments, it can be the electrode array **130** electrically connecting the metal interconnections, and not the electrode array **530**.

In addition, in the present embodiment, the TMR component **740** is in direct contact with the electrode array **130** and the electrode array **530**. In other embodiments, as shown in FIG. **10**, the TMR sensor **1000** can further includes a number of contact plugs **160** and a number of contact plugs **170**. The contact plugs **160** are formed in the insulating layer **120** and electrically connect the electrodes **132** with the TMR component **740**. While the contact plugs **170** are formed in the insulating layer **120** and electrically connect the electrodes **532** with the TMR component **740**. In other words, the TMR component **740** is electrically connected to the electrode array **130** by the contact plugs **160**, and electrically connected to the electrode array **530** by the contact plugs **170**.

In summary, the TMR sensor of the present invention belongs to a CIP-TMR sensor with contact electrodes disposed at a same level. That is, the electrodes directly or indirectly connecting to the TMR component can be formed in single metal layer. Thus, comparing to the CPP-TMR sensor, the CIP-TMR sensor of the present invention can be manufactured by a more simplified process, thereby reducing the production cost. Moreover, in a preferable embodiment of the present invention, the electrodes can be disposed below the TMR component. In other words, after the formation of TMR component, no metal layer is disposed above. The deterioration due to the metal-layer manufacturing process such as thermal energy accumulation, stress accumulation and interface diffusion will be avoided and the performance of the TMR component can be therefore maintained.

Additionally, the TMR sensor of the present invention can include the TMR component comprising a strip-shaped MTJ unit electrically connected to multiple floating electrodes. Thus, the switching field can be reduced due to lower shape anisotropy and the MR ratio can be increased due to the multiple-tunneling effect. Both factors contribute to the proposed TMR sensor with higher sensing signal and sensitivity.

While the invention has been described in terms of what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention needs not be limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims which are to be accorded with the broadest interpretation so as to encompass all such modifications and similar structures.

What is claimed is:

1. A tunneling magnetoresistance sensor, comprising:

a substrate;

an insulating layer disposed on the substrate;

a tunneling magnetoresistance component in contact with the insulating layer, the tunneling magnetoresistance component comprising at least one magnetic tunneling junction unit; and

a first electrode array disposed in contact with the insulating layer and, the first electrode array comprising a plurality of first electrodes;

the first electrode array being electrically connected to the tunneling magnetoresistance component to form a current-in-plane tunneling conduction device, wherein each of the at least one magnetic tunneling junction unit is electrically connected to at least two neighboring first electrodes of the first electrode array.

2. The tunneling magnetoresistance sensor of claim **1**, wherein the first electrode array is formed in a single metal layer and in direct contact with the tunneling magnetoresistance component correspondingly.

3. The tunneling magnetoresistance sensor of claim **1**, wherein the first electrode array is located above the tunneling magnetoresistance component correspondingly.

4. The tunneling magnetoresistance sensor of claim **1**, wherein the first electrode array is located below the tunneling magnetoresistance component correspondingly.

5. The tunneling magnetoresistance sensor of claim **1**, further comprising a plurality of first contact plugs, the first contact plugs being disposed in the insulating layer and electrically connecting the first electrodes with the at least one magnetic tunneling junction unit.

6. The tunneling magnetoresistance sensor of claim **1**, further comprising a second electrode array, the second electrode array comprising a plurality of second electrodes, the second electrode array being electrically connected to the tunneling magnetoresistance component to form a current-in-plane tunneling conduction device.

7. The tunneling magnetoresistance sensor of claim **6**, wherein the tunneling magnetoresistance component is located between the first electrode array and the second electrode array.

8. The tunneling magnetoresistance sensor of claim **6**, further comprising a plurality of second contact plugs, the second contact plugs being disposed in the insulating layer and electrically connecting the second electrodes with the magnetic tunneling junction units.

9. The tunneling magnetoresistance sensor of claim **1**, wherein the at least one magnetic tunneling junction unit is a strip-shaped magnetic tunneling junction unit.

10. The tunneling magnetoresistance sensor of claim **9**, wherein the plurality of first electrodes are electrically connected to the strip-shaped magnetic tunneling junction unit.

11. The tunneling magnetoresistance sensor of claim **9**, further comprising a plurality of second electrodes electrically connected to the strip-shaped magnetic tunneling junction unit.

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